WIDE CHORD FAN BLADE

BACKGROUND OF THE INVENTION

Aircraft and aircraft engine design have always strived for reduced weight and greater efficiency. Other factors affecting aircraft and engine design involve cost and size, including the maintenance of the aircraft and the engines. With increased emphasis in these areas, future aircraft are growing in size, requiring either more thrust from the engines or additional engines. Reduced maintenance costs and initial costs can be achieved by enlarging the engines, increasing the thrust developed by the engines rather than by increasing the number of engines on a particular aircraft. However, as the engines grow larger, weight reduction becomes paramount as all the engine components are required to grow.

The next generation of commercial high thrust engines will have fan diameters ranging in size from 106 inches to 124 inches. The increased fan diameters will require longer blades. The longer blades will have wider chords for increased efficiency. The chord, which is the axial straight line dimension between the trailing edge and the leading edge of the airfoil, will grow with the increased blade size. Typical fan blades currently have tip chords of about 8 to 12 inches, while the wide chord fan blades for the larger engines will have tip chords in the range of about 20 to 28 inches. The wider chord blades offer the increased efficiency because they have greater stability margins and move the air more efficiently across the blade face due to their longer chords. The increased stability allows the blade to be manufactured without a mid-span shroud, which on current Titanium blades causes a decrease in blade efficiency. Increased blade efficiency is important in high bypass turbine engines because about 75% to 80% of the air bypasses the core engine combustor and is used to provide direct thrust.

The majority of the current fan blades in turbofan engines are solid titanium construction. Another fan blade construction utilizes titanium skin over a titanium honeycomb core. The manufacture of a solid titanium wide chord fan blade is prohibitive because of the initial cost of the materials and the ultimate weight of the blade upon completion. Thus, a solid fan blade for a larger engine would probably be more of a standard chorded blade with a mid span shroud.

A proposed solution to the problem of weight and cost for blades in larger engines is an all-composite wide chord fan blade. A large engine having all-composite wide chord fan blades has a projected weight savings of about 800 pounds over a large engine having standard chorded fan blades. The all-composite wide chord fan blade would also display a somewhat smaller, but nevertheless substantial, weight savings over titanium skin/titanium honeycomb blades.

The concept of all-composite blades has been attempted in the past. However, these blades have never been successfully implemented for several reasons. One early program developed erosion problems due to the poor erosion characteristics of the applied coating and to the lack of a metallic leading edge. The coating could not withstand rain droplet impacts without sustaining damage. Once the exterior coating was damaged, exposing the underlying laminated composite structure, the underlying composite structure was subjected to water damage from water ingestion and further impacts.

These conditions caused severe delaminations in the blades and led to blade failure in relatively short times.

Another composite fan blade program was discontinued when the blades could not withstand small bird impacts (bird size of about 2.0-4.0 ounces) without delaminations under the leading edge. Although the blade could pass FAA requirements at the time, maintainability of the blades was projected to be a problem because these delaminations were "invisible", that is undetectable by visual inspection, and could propagate, causing potentially serious blade failures. It was believed that engines would always see impacts in this size range that would not be detected, so that the incident would go unnoticed, even though internal damage would have occurred to the blade.

Thus, there exists a need to provide a composite wide chord fan blade which can withstand typical impacts and operating conditions experienced by modern turbofan engines. The composite blade should offer stiffness and light weight, which are important as engine size and thrust continue to increase. However, the composite fan blade must be capable of equivalent or better performance at all operating conditions, including impact, of current metallic fan blades. Maintenance requirements should be comparable to current fan blades, and desirably should be reduced.

SUMMARY OF THE INVENTION

The present invention is a damped, energy absorbing, laminated airfoil. The airfoil, of wide chord configuration, has a tip portion, a dovetail root section, the dovetail root section having flank surfaces, a leading edge extending from the tip portion to the root section, and a trailing edge oppositely disposed to the leading edge and extending from the tip portion to the root section. The tip chord is larger than the conventional chords of current engines, being at least about 20 inches, and as large as 28 inches. The airfoil is comprised of alternating layers of thin metallic foil and elastomeric layers, thereby forming a laminated composite airfoil. The metallic foil forms the first and the last layers of the laminated structure, so that the outer surfaces of the airfoil are made from metallic foil. The alternating elastomeric layers provide the means of bonding the metallic foil layers, while providing inherent energy absorbing characteristics to the structure. At least one hole or aperture, and preferably a plurality of holes or apertures, are drilled into each dovetail flank surface extending at least partially through of the dovetail. A high strength metal member is then disposed through each of the dovetail root section apertures across the alternating layers and secured in place by adhesive bonding, thereby further securing the layers and providing additional strength. The adhesive bonding agent is preferably the same material used to secure the metallic foil layers together. A metal sheath is secured to the leading edge of the airfoil by adhesive bonding. In a preferred embodiment, the high strength metal member is a titanium-base pin, while the metallic foil in the airfoil is a titanium alloy foil or a stainless steel alloy foil having a uniform thickness of about 0.005 to about 0.015 inches. The leading edge sheath is a nickel alloy foil having a thickness of about 0.008 to about 0.012 inches on each of the edges and increasing to a thickness of about 0.040 to about 0.060 inches at the airfoil leading edge. Alternatively, the leading edge sheath is a stainless steel alloy or